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(54) Low voltage electromagnetic controlled riveting process

Nierdespannungs-Elektromagnetische Nietverfahren zum gesteuerten Nieten

Procédé de rivetage électromagnétique à basse tension controlé

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Description

Background of the Invention

1. Field of the Invention

[0001] The present invention relates to a low-voltage electromagnetic riveting method, and more particularly to a method for controlled and efficient low-voltage electromagnetic riveting.

2. Background Information

[0002] Riveting machines are well known and in wide use throughout the aerospace industry, as well as in other industries. Rivets provide the best known technique for fastening an aerodynamic skin to a frame to provide a strong, aerodynamically smooth surface. Rivets are also used in the interior structure of an aircraft, since they are the lightest and least expensive way of fastening structural components together.

[0003] One form of riveting uses a low voltage electromagnetic riveting (LVEMR) system 100, as shown in Fig. 1. The LVEMR system 100 provides a controlled amount of energy in a single pulse and is typically smaller and less cumbersome than a pneumatic or hydraulic system. Further, the LVEMR system has almost no mass so it only has nominal reactionary forces. The LVEMR system 100 shown in Fig. 1 incorporates two electromagnetic actuators, a first actuator 101 and a second actuator 112, which are positioned on opposite sides of first and second workpieces 114 and 115, respectively. The first and second work pieces 114 and 115 are sandwiched together and a hole has been drilled through them to accommodate a rivet 93. The first and second actuators 101 and 112 each include a body 116 in which is positioned a driver 118 and a coil 120. A rivet die 92 is coupled to the driver 118 and is forced against the rivet 93. Also, there may be a recoil mass 123 which is typically secured to a rear surface of the coil 120. Extending from the recoil mass 123 is an air cylinder rod 124, which extends out of the body 116 into a two-chamber air cylinder 126. Associated pressure relief valves and other control elements are shown diagramatically as block 128. The elements of block 128 are responsible for initially positioning the driver 118 and its rivet die 92 against a head of the rivet 93.

[0004] Power is supplied to the system 100 by means of a power supply 130. A DC output from the supply 130 is used to charge a bank of capacitors in circuit 132 to a selected voltage. The voltage selected is based on the force necessary to accomplish the desired riveting task. The circuit 132 includes an electronic switch positioned between the capacitors and the coil 120.

[0005] A trigger signal from a firing circuit 134 activates the electronic switch, dumping the charge of the capacitor bank in circuit 132 into the coil 120. A current pulse is induced into the coil 120 causing strong eddy currents in a copper plate 119 located at the base of the driver 118. This creates a very strong magnetic field that provides a repulsive force relative to the coil 120. The driver 118 is propelled forward with a large force causing the rivet die 92 to upset the head of the rivet 93. A more detailed discussion of low voltage electromagnetic riveting can be found in U.S. Patent No. 4,862,043.

[0006] Once the LVEMR system 100 has upset the rivet 93, a fastened assembly 140 is created as shown in Figure 1B. The assembly 140 includes a deformed rivet 146, having a head 142 and a tail 154. The hole drilled into the first and second workpieces 114 and 115 includes a countersink 148 drilled into the second workpiece 115 to receive the head 142 of the deformed rivet 146.

[0007] Unfortunately, the fastened assembly 140, when produced by the LVEMR system 100 described above, has significant gaps 150 between the head 142 of the deformed rivet 146 and the countersink 148. The gaps 150 are undesirable since they could lead to early corrosion of the deformed rivet 146, causing it to weaken and prematurely fail. Accordingly, for the foregoing reasons, there is a need in the art for a controlled low-voltage electromagnetic riveting process that mitigates the gaps 150 between the rivet head 142 and the countersink 148.

[0008] From the United States patent US 5,471,865, a riveter is known comprising two riveting guns each including a pair of coil means, one of which is drivingly associated with a forming tool or anvil. The use of a pair of coil means per riveting gun instantiates a complex contraption. In order to achieve a more preferable method for riveting with an equal force from both sides, the present invention provides a method for mitigating gaps between a deformed head of a slug rivet and a countersink according to claim 1.

[0009] Furthermore the present invention provides a method for controlled low-voltage electromagnetic riveting according to claim 9.

[0010] Further embodiments of the present invention are laid out in the dependent claims.

Brief Description of the Drawings

[0011] These and other features, aspects, and advantages of the present invention will be better understood with regard to the following description, appended claims, and accompanying drawings wherein:

Figure 1A shows a block diagram of a prior art low-voltage electromagnetic riveting system;

Figure 1B shows a rivet deformed by the riveting system of Fig. 1A;

Figure 2 shows a force vs. time graph applied to a rivet during its deformation into a hole having a countersink;

Figure 3 shows a force vs. time graph applied to a rivet using a process and apparatus for mitigating gaps according to the present invention;

Figure 4 shows a desired rivet protrusion to mitigate gaps according to a first embodiment of the present invention;

Figure 5 shows a desired forming die configuration according to the first embodiment of the present invention;

Figure 6A shows a schematic diagram of a low-voltage electromagnetic driving system according to a second embodiment of the present invention;

Figure 6B shows a side view of a load cell and driver of the low-voltage electromagnetic driving system of the second embodiment;

Figure 7A shows a force vs. time graph for a rivet head and rivet tail having applied forces that are out of phase and have different magnitudes;

Figure 7B shows a force vs. time graph for the rivet head and the rivet tail having applied forces that are in phase but have different magnitudes; and

Figure 7C shows a force v. time graph for the rivet head and the rivet tail having applied forces that are in phase and have the same peak magnitude.

Detailed Description of the Preferred Embodiments

[0012] The following process and apparatus assist in controlling and balancing the forces applied to a rivet. Such control mitigates gaps between a head of a rivet and a countersink into which it is deformed. Other advantages include more accurate control over rivet interferences and a reduction in reactive forces applied to an object being riveted.

[0013] It has been discovered that to mitigate the gaps between the rivet and the countersink, it is essential to maintain an equal force on the head and a tail of the rivet throughout the riveting process. Unfortunately, when the workpiece or assembly to be riveted has been countersunk to receive a deformed rivet head, simultaneous activation of two opposing LVEMR guns will not produce equal forces on the rivet head and the rivet tail over the duration of time that the rivet is deformed.

[0014] Low voltage electromagnetic rivet (LVEMR) guns are typically dynamic and used in an open loop system, as such, they offer no method of "real-time" force control during the rivet-forming process. Because the LVEMR guns are used in an open loop, they produce a dissimilar force on the head and tail over time, as shown in Fig. 2. However, the forming process can be manipulated to compensate for the force unbalancing effects of a countersink within a workpiece. This manipulation is accomplished by selecting process variables so that the head and tail of the rivet have similar forming characteristics over time as shown in Fig. 3.

[0015] In a first embodiment, as shown in Figs. 4 and 5, the force-displacement relationship of a head 21 and tail 23 of a rivet 22 are manipulated via the forming characteristics of the rivet 22 to maintain a force balance between the head 21 and the tail 22.

[0016] Five factors typically affect the forming characteristics of the rivet 22, and therefore can be used to affect the force-displacement relationship of the head 21 and the tail 23. First, there is the mechanical properties of the rivet 22, i.e. the stress - strain relation. Since rivets are typically composed of a homogenous alloy, there is no difference in the material adjacent the head 21 and the tail 23. Therefore, this factor does not create a difference in the force-displacement between the head 21 and the tail 23. Second, the diameter of the rivet will affect the force-displacement along the rivet 22. Any difference in force-displacement due to diameter effects between the head 21 and the tail 23 can be eliminated by using a slug rivet, which has a constant diameter throughout.

[0017] The third factor affecting the force-displacement relationship of the rivet 22 is the amount of rivet 22 that extends out of the primary sheet 24 and the secondary sheet 26. This includes a head protrusion 28 of the rivet 22 above a countersink 25 in the primary sheet 24 to be coupled to the secondary sheet 26, as shown in Fig. 4. The third factor also includes a tail protrusion 30 from the secondary sheet 26. The larger the protrusion values for the head protrusion 28 and the tail protrusion 30, the more the displacement of the protrusion for a given force, i.e., a soft force-displacement relationship.

[0018] The fourth factor affecting the force-displacement is the geometry of the countersink 25, and the fifth factor is the design of a head die 32 and a tail die 34 used to upset the rivet 22, as shown in Figs. 4 and 5. Captivating dies, such as the tail die 34, and deep countersinks, such as the countersink 25, create a stiffer force-displacement relationship. Therefore, there is less displacement of the rivet 22 for a given force when using dies, such as the tail die 34, and countersinks, such as countersink 25, that prevent the material of the rivet 22 from flowing outward when it is upset.

[0019] In the first embodiment, a preferred combination of the above-described factors maintains a balanced force, i.e. equal force on the tail 1 the head 23, throughout the riveting process which results in the elimination of any gaps between the deformed head and the countersink 25. Referring to Fig. 4, the preferred combination has the amount of head protrusion 28 at a length that is five to ten percent less than the length of the tail protrusion 30. In other words:

$$\text{Head Protrusion} = (1 - [.05 \text{ to } .10]) (\text{Tail Protrusion}).$$

Further, referring to Fig. 4, the tail protrusion 30 is preferably .9 to 1.3 times a diameter 19 of the rivet 22. In other words:

$$\text{Tail Protrusion} = [.9 \text{ to } 1.3] \text{ Rivet Diameter}.$$

[0020] Referring to Fig. 5, the depth 44 of a contact surface 36 of the tool die 34 in the preferred combination must be similar to, i.e. within 20% of, the depth 42 of the countersink 25. The contact surface 38 of the head die 32 is preferably flat. Also, an upper diameter 40 of the tail die 34 must be similar to a countersink diameter 37, i.e. the upper diameter 40 must be within 20% of the countersink diameter 37. Finally, an upper angle or taper 48 ofthe edge of the die surface of the tail die 34 must be similar, i.e. to an upper angle or taper 46 of the countersink, i.e. within 20%.

[0021] In a second embodiment, the force applied to a head and a tail of a rivet is balanced, i.e. applied equally over time, by controlling the rivet upsetting process using a monitoring and application assembly 50, shown in Fig. 6A.

[0022] When riveting a workpiece that has a countersink, using two rivet guns, one at a head side and the other at a tail side of a rivet 22, the force applied to the head side is usually out of phase with and has a different magnitude than the force applied to the a tail side of the rivet 22, as shown in Fig. 7A. However, the assembly 50 can be used to create the proper differential voltage and timing so that the forces applied to the head and tail side of the rivet 22 are balanced, i.e., the forces applied over time to each side are nearly identical.

[0023] The assembly 50 includes a first load-cell 56, and a second load-cell 58, used to monitor the force applied by the electromagnetic riveter during the riveting process. Each of the first and second load-cells 56 and 58 is mounted on respective first and second drivers 52 and 54, near its respective first and second rivet die 60 and 62. Preferably, each of the first and second load-cells 56 and 58 is positioned no less than three inches from its respective first and second rivet die 60 and 62.

[0024] The first load cell 56 and the second load cell 58 are identical and are described with reference to the first load cell 56, shown in Fig. 6B. The load cell 56 includes a piezo-electric quartz cell 66, preferably a PCB Model 204M device. An integral cable 68 extends from the quartz cell 66 and is coupled to a waveform analyzer 64, such as a Nicolet Module 2580, which digitally stores the electrical waveform produced by the quartz cell 66 when a force is applied to it. By subjecting the quartz cell 66 to known forces and monitoring the output, a conversion graph can be created, where a particular electrical waveform can be converted to a force-over-time waveform.

[0025] As shown in Fig. 6B, the quartz cell 66 is coupled to the driver 56 and the head die 60, so that it will receive and register at least 95% of the force applied by the driver 56, yet dampen external noise. Two pieces of tape 70a and 70b, preferably Capton tape, are positioned on first and second sides of the quartz cell 66 that are orthogonal to a longitudinal axis of the driver 52. The two pieces of tape 70a and70b help dampen noise produced by the driver 56, which could interfere with an accurate measurement by the quartz cell 66. First and second respective steel washers 72a and 72b are respectively positioned adjacent the Capton tapes 70a and 70b. The first and second steel washers 72a and 72b, as well as the quartz cell 66, are annular, allowing a stud 74 to pass through. The stud 74 is preferably a copper beryllium threaded stud. Copper beryllium is preferred since it may be threaded to the driver 52 and the head die 60 coupling the two physically yet allowing 95% of the force from the driver 52 to pass through the load cell 56, instead of the stud 74. Optionally, a portion 76 of the driver 52 may be threadingly detachable to allow easy maintenance and replacement of the load cell 58.

[0026] The phase and magnitude of the force applied by the first and second drivers 52 and 54 are directly caused by a "charge dump" from a respective first and second capacitor bank 78 and 80 charged by a power cell 82 and controlled by a firing circuit 84. The firing circuit has a first phase and amplitude voltage control 86 for controlling the phase and magnitude of force, via voltage, of the first driver 52, and a second phase and amplitude control 88 for controlling the phase and magnitude of force, via voltage, of the second driver 54.

[0027] There are four steps in determining the proper differential voltage and timing delay to balance the forces on the head and tail of the rivet 22. First, the desired process conditions, i.e. the desired rivet protrusion and die geometry, must be selected The forces are then monitored by the first and second load cells 56 and 58 during the rivet-forming process with no differential voltage and no timing delay, yielding a force-over-time graph as shown in Fig. 7A. The force over time applied to the rivet 22 is recorded by the waveform analyzer 64.

[0028] Next, the timing delay is adjusted to bring the forces into phase. The forces are in phase when the peak forces are reached simultaneously, as shown in Fig. 7B. It is important to adjust phase first since amplitude often changes when the phase is changed. For example, in Fig. 7A, the head force has the greatest magnitude, while in Fig. 7B, the tail force has the greatest magnitude. The proper amount of delay is approximately equal to the difference in time between the head and tail peak forces. As shown in Figure 7A, if the phase difference 60 is 50 μs, where the head force precedes tail force, then the head force should be delayed about 50 μs by adjusting the phase using the first control 86.

[0029] For the third step, the voltages are adjusted to produce equal force magnitude, i.e. the greater force is reduced or the lesser force is increased by changing charge voltage via the firing circuit 84. In the example shown in 7B, the tail force needs to be decreased by adjusting voltage amplitude using the second control 88 until the tail force equals head force. It is most desirable if the entire force on the tail and head matches for their duration. However, if this match is not possible, it is important that the force peaks 61, i.e., the force having the greatest area, as shown in Fig. 7C, are as equal as possible. If the forces cannot be entirely aligned, then they must at least substantially match in this area.

[0030] Finally, the second and third steps are repeated until well-matched curves are achieved as in Fig. 7C.

[0031] With the present invention, it is possible to apply an equal force to a rivet head and tail, even when the head is upset into a countersink. By these arrangements, gaps between a deformed head and a countersink can be mitigated and interferences better controlled.

[0032] While the detailed description above has been expressed in terms of specific examples, those skilled in the art will appreciate that many other configurations could be used to accomplish the purpose of the disclosed inventive apparatus. Accordingly, it will be appreciated that various equivalent modifications of the above-described embodiments may be made without departing from the scope of the invention. Therefore, the invention is to be limited only by the following claims.

Claims

1. A method for mitigating gaps (150) between a deformed head (21) of a slug rivet (22) and a countersink (25) within a first workpiece of two workpieces in an assembly that is coupled by a low-voltage electromagnetic riveter (50) having a head side actuator (32) and a tail side actuator (34), said method including the steps of:

selecting a slug rivet (22) that uniformly deforms at a tail (23) and a head (21) of the rivet; and

positioning the volume of the rivet within the assembly such that prior to actuation of the head side actuator and the tail side actuator, the tail of the rivet extends out of a surface of a second workpiece of the two workpieces by a length from .9 to 1.3 times a diameter of the rivet; and the head of the rivet extends out of a base of the countersink by a length that is 5% to 10% less than the length of the tail of the rivet was extended out of the second workpiece surface and such that the force applied over time to the head of the rivet by the head side actuator equals a force applied over time to the tail of the rivet by the tail-side actuator.

2. The method for mitigating gaps according to claim 1, wherein said step of positioning the volume of the rivet further includes the step of:

upsetting the tail (23) of the rivet with a tail die (34,36) coupled to said tail side actuator, said tail die having a contact surface with a depth (44), diameter, and taper that is substantially the same as a depth, diameter, and taper of the countersink.

3. The method for mitigating gaps according to claim 2, wherein the dimensions of said die are within 20% of the dimensions of said countersink.

4. The method according to claim 2, wherein the dimensions of said die are preferably within 5% of the dimensions of said countersink.

5. Method according to any of claims 2, 3 or 4, comprising:

upsetting the head of the rivet with a head die having a flat contact surface; and

upsetting the tail of the rivet with the tail die, wherein the tail die has an upper diameter within 20% of the depth of the countersink, and wherein the tail die has an upper diameter within 10 degrees of the upper angle of the countersink.

6. A method according to any of the foregoing claims, in which the low-voltage electromagnetic riveter (50), includes a head-side driver (52), having a first load cell (56), and a tail side driver (54), having a second load cell (58), and a firing control circuit (84,86,88) capable of controlling phase and magnitude of force applied by the head-side driver and the tail-side driver, said method comprising the steps of:

(a) positioning a first test rivet within the assembly;

(b) monitoring a first output of the first load cell and the second load cell while the first test rivet is upset to determine the phase and the magnitude of the force applied to a head and a tail of the rivet respectively by the head side driver and the tail side driver;

(c) comparing the first output of the first load cell and the second load cell that occurred when the first test rivet was upset;

(d) adjusting the phase of one of the force applied by the head driver and the force applied by the tail driver so that the phase of the force applied by the head driver matches the phase of the force applied by the tail driver.

(e) positioning a second test rivet within the assembly;

(f) monitoring a second output of the first load cell and the second load cell while the second test rivet is upset to determine the phase and the magnitude of the force applied to the head and the tail of the second test rivet respectively by the head side driver and the tail side driver;

(g) comparing the second output of the first load cell and the second load cell that occurred when the second test rivet was upset; and

(h) adjusting the magnitude of one of the force applied by the head driver and the force applied by the tail driver so that the magnitude of the force applied by the tail driver equals the magnitude of the force applied by the head driver.

7. The method according to claim 6, further including the step of repeating steps (a) through (h) until the first and second driver have a phase and a magnitude over time that are substantially equal.

8. The method according to claim 6, further including the steps of repeating steps (a) through (h) until, at least at a peak area of force over time, the first and second driver have a phase and a magnitude that are substantially equal.

9. A method for controlled low-voltage electromagnetic riveting of a slug rivet within two workpieces, a first of the two workpieces including a countersink, said method comprising the steps of:

positioning a slug rivet within the two workpieces such that a tail of the rivet extends out of a surface of a second workpiece of the two workpieces by a length from .9 to 1.3 times a diameter of the rivet; and the head of the rivet extends out of a base of the countersink by a length that is 5% to 10% less than the length of the tail of the rivet was extended out of the second workpiece surface;
monitoring the force applied over time to a head and tail of a rivet during a deformation of the rivet by the low-voltage electromagnetic riveting;
adjusting a phase of the force applied to at least one of a location of the head and the tail of the rivet so that the phase of the force applied to the location of the head of the rivet equals the phase of the force applied to the location of the tail of the rivet; and
adjusting a magnitude of the force applied to the location of the rivet head and the tail of the rivet so that the magnitude of the force applied to the rivet head equals the force applied to the location of the tail of the rivet.

Patentansprüche

1. Verfahren zum Verringern von Zwischenräumen (150) zwischen einem deformierten Kopf (21) eines Niets (22) und einer Senkung (25) innerhalb eines ersten Werkstücks von zwei Werkstücken in einer Anordnung, welche von einer elektromagnetischen Niederspannungs-Nietvorrichtung (50), die einen kopfseitigen Aktuator (32) und einen endseitigen Aktuator (34) umfasst, gekoppelt wird, wobei das Verfahren folgende Schritte umfasst:

- Auswählen eines Niets (22), welcher sich gleichförmig an einem Ende (23) und einem Kopf (21) des Niets deformiert, **gekennzeichnet durch**
- Positionieren des Volumens des Niets in der Anordnung derart, dass vor einer Betätigung des kopfseitigen Aktuators und des endseitigen Aktuators das Ende des Niets aus einer Oberfläche eines zweiten Werkstücks der zwei Werkstücke um eine Länge des 0,9 - 1,3-fachen eines Durchmessers des Niets herausragt; und wobei der Kopf des Niets aus einer Basis der Senkung mit einer Länge herausragt, welche 5 % bis 10 % kleiner als die Länge des Endes des Niets ist, die aus der Oberfläche des zweiten Werkstücks herausragt, und dass eine über die Zeit auf den Kopf des Niets von dem kopfseitigen Aktuator angewendete Kraft gleich einer auf das Ende des Niets durch den endseitigen Aktuator angewendeten Kraft über die Zeit ist.

2. Verfahren zum Verringern von Zwischenräumen nach Anspruch 1, wobei der Schritt des Positionierens des Volumens des Niets weiterhin folgenden Schritt umfasst:

- Stauchen des Endes (23) des Niets mit einem mit dem endseitigen Aktuator gekoppelten Endstempel (34, 36), wobei der Endstempel eine Kontaktoberfläche mit einer Tiefe (44), einem Durchmesser und einer Abschrägung aufweist, welche im Wesentlichen gleich einer Tiefe, einem Durchmesser und einer Abschrägung der Senkung sind.

3. Verfahren zum Verringern von Zwischenräumen gemäß Anspruch 2, wobei die Abmessungen des Stempels von den Abmessungen der Senkung um höchstens 20% abweichen.

4. Verfahren nach Anspruch 2, wobei die Abmessungen des Stempels bevorzugt um höchstens 5% von den Abmessungen der Senkung abweichen.

5. Verfahren nach einem der Ansprüche 2, 3 oder 4, umfassend:

- Stauchen des Kopfes des Niets mit einem Kopfstempel, welcher eine flache Kontaktoberfläche aufweist, und
- Stauchen des Endes des Niets mit dem Endstempel, wobei der Endstempel einen um höchstens 20% von der Tiefe der Senkung abweichenden oberen Durchmesser aufweist und wobei der Endstempel einen oberen Durchmesser innerhalb von 10 Grad des oberen Winkels der Senkung aufweist.

6. Verfahren nach einem der vorhergehenden Ansprüche, wobei die elektromagnetische Niederspannungs-Nietvorrichtung (50) einen kopfseitigen Treiber (52) mit einer ersten Lastzelle (56), und einen endseitigen Treiber (54) mit einer zweiten Lastzelle (58) und eine Abschusssteuerschaltung (84, 86, 88),

welche in der Lage ist, Phase und Größe einer Kraft zu steuern, welche durch den kopfseitigen Treiber und den endseitigen Treiber angewendet wird, aufweist,
wobei das Verfahren folgende Schritte umfasst:

(a) Positionieren eines ersten Testniets in der Anordnung,
(b) Überwachen einer ersten Ausgabe der ersten Lastzelle und der zweiten Lastzelle, während der erste Testniet gestaucht wird, um die Phase und die Größe der auf einen Kopf bzw. ein Ende des Niets von dem kopfseitigen Treiber bzw. dem endseitigen Treiber angewendeten Kraft zu bestimmen,
(c) Vergleichen der ersten Ausgabe der ersten Lastzelle und der zweiten Lastzelle, welche auftrat, als der erste Testniet gestaucht wurde,
(d) Anpassen entweder der durch den Kopftreiber angewendeten Kraft oder der durch den Endtreiber angewendeten Kraft derart, dass die Phase der von dem Kopftreiber angewendeten Kraft mit der Phase der durch den Endtreiber angewendeten Kraft übereinstimmt,
(e) Positionieren eines zweiten Testniets in der Anordnung,
(f) Überwachen einer zweiten Ausgabe der ersten Lastzelle und der zweiten Lastzelle, während der zweite Testniet gestaucht wird, um die Phase und die Größe der auf den Kopf bzw. das Ende des zweiten Testniets durch den kopfseitigen Treiber bzw. den endseitigen Treiber angewendeten Kraft zu bestimmen,
(g) Vergleichen der zweiten Ausgabe der ersten Lastzelle und der zweiten Lastzelle, welche auftrat, als der zweite Testniet gestaucht wurde, und
(h) Anpassen der Größe entweder der durch den Kopftreiber angewendeten Kraft oder der durch den Endtreiber angewendeten Kraft derart, dass die Größe der durch den Endtreiber angewendeten Kraft gleich der Größe der durch den Kopftreiber angewendeten Kraft ist.

7. Verfahren nach Anspruch 6, weiterhin umfassend den Schritt des Wiederholens der Schritte (a) bis (h), bis der erste und zweite Treiber über die Zeit eine Phase und eine Größe haben, welche im Wesentlichen gleich sind.

8. Verfahren nach Anspruch 6, weiterhin umfassend die Schritte des Wiederholens der Schritte (a) bis (h) bis zumindest in einem Spitzenbereich der Kraft über die Zeit der erste und der zweite Treiber eine Phase und eine Größe aufweisen, welche im Wesentlichen gleich sind.

9. Verfahren zum gesteuerten elektromagnetischen Niederspannungs-Nieten eines Niets in zwei Werkstücken, wobei ein erstes der zwei Werkstücke eine Senkung umfasst, wobei das Verfahren folgende Schritte umfasst:

- Positionieren eines Niets innerhalb der zwei Werkstücke, so dass ein Ende des Niets aus einer Oberfläche eines zweiten Werkstücks der zwei Werkstücke um eine Länge des 0,9 - 1,3-fachen eines Durchmessers des Niets herausragt; und wobei der Kopf des Niets aus einer Basis der Senkung mit einer Länge herausragt, welche 5 % bis 10 % kleiner als die Länge des Endes des Niets ist, die aus der Oberfläche des zweiten Werkstücks herausragt;
- Überwachen der während einer Deformation des Niets durch das elektromagnetische Niederspannungs-Nieten auf einen Kopf und ein Ende eines Niets angewendeten Kraft über die Zeit,
- Anpassen einer Phase der auf zumindest einen Ort des Kopfes und des Endes des Niets angewendeten Kraft, so dass die Phase der auf den Ort des Kopfes des Niets angewendeten Kraft gleich der Phase der auf den Ort des Endes des Niets angewendeten Kraft ist, und
- Anpassen einer Größe der auf den Ort des Nietenkopfes und des Endes des Niets angewendeten Kraft, so dass die Größe der auf den Nietenkopf angewendeten Kraft gleich der auf den Ort des Endes des Niets angewendeten Kraft ist.

Revendications

1. Procédé pour réduire des interstices (150) entre une tête déformée (21) d'un rivet à former (22) et un chanfrein (25) à l'intérieur d'une première pièce de travail sur deux pièces de travail dans un ensemble qui est couplé par une riveteuse électromagnétique à basse tension (50) possédant un actionneur côté tête (32) et un actionneur côté tige (34), ledit procédé comprenant les étapes consistant à :

choisir un rivet à former (22) qui se déforme d'une manière uniforme au niveau d'une tige (23) et d'une tête (21) du rivet ; et
positionner le volume du rivet à l'intérieur de l'ensemble de telle sorte que, préalablement à l'actionnement de l'actionneur côté tête et de l'actionneur côté tige, la tige du rivet dépasse d'une surface d'une seconde pièce de travail sur les deux pièces de travail d'une longueur faisant 0,9 à 1,3 fois un diamètre du rivet ; et la tête du rivet dépasse d'une base du chanfrein d'une longueur qui est de 5 % à 10 % inférieure à la longueur dont la tige du rivet dépasse de la surface de la seconde pièce de travail, et de telle sorte

que la force appliquée dans le temps sur la tête du rivet par l'actionneur côté tête soit égale à une force appliquée dans le temps sur la tige du rivet par l'actionneur côté tige.

2. Procédé pour réduire des interstices selon la revendication 1, dans lequel ladite étape de positionnement du volume du rivet comprend par ailleurs l'étape consistant à :

refouler la tige (23) du rivet à l'aide d'une bouterolle côté tige (34, 36) qui est couplée au dit actionneur côté tige, ladite bouterolle côté tige possédant une surface de contact ayant une profondeur (44), un diamètre et une conicité, qui sont sensiblement identiques à la profondeur, au diamètre et à la conicité du chanfrein.

3. Procédé pour réduire des interstices selon la revendication 2, dans lequel les dimensions de ladite bouterolle sont inférieures, de moins de 20 %, aux dimensions dudit chanfrein.

4. Procédé selon la revendication 2, dans lequel les dimensions de ladite bouterolle sont inférieures, de moins de 5 % de préférence, aux dimensions dudit chanfrein.

5. Procédé selon l'une quelconque des revendications 2, 3 ou 4, comprenant les étapes consistant à :

refouler la tête du rivet à l'aide d'une bouterolle côté tête comportant une surface de contact plane ; et
refouler la tige du rivet à l'aide de la bouterolle côté tige, la bouterolle côté tige possédant un diamètre supérieur qui est inférieur à 20 % de la profondeur du chanfrein, et la bouterolle côté tige possédant un diamètre supérieur qui est inférieur à 10 degrés de l'angle supérieur du chanfrein.

6. Procédé selon l'une quelconque des revendications précédentes, dans lequel la riveteuse électromagnétique à basse tension (50) comprend une unité d'entraînement côté tête (52) possédant une première cellule de charge (56), et une unité d'entraînement côté tige (54) possédant une seconde cellule de charge (58), ainsi qu'un circuit de commande d'activation (84, 86, 88) qui est apte à contrôler la phase et l'intensité de la force appliquée par l'unité d'entraînement côté tête et par l'unité d'entraînement côté tige, ledit procédé comprenant les étapes consistant à :

(a) positionner un premier rivet de test à l'intérieur de l'ensemble ;
(b) contrôler un premier signal de sortie de la première cellule de charge et de la seconde cellule de charge tout en refoulant le premier rivet de test de façon à déterminer la phase et l'intensité de la force appliquée sur une tête et une tige du rivet respectivement par l'unité d'entraînement côté tête et l'unité d'entraînement côté tige ;
(c) comparer le premier signal de sortie de la première cellule de charge et celui de la seconde cellule de charge, qui sont apparus lorsque le premier rivet de test a été refoulé ;
(d) ajuster la phase de l'une de la force appliquée par l'unité d'entraînement côté tête et de la force appliquée par l'unité d'entraînement côté tige de telle sorte que la phase de la force appliquée par l'unité d'entraînement côté tête soit égale à la phase de la force appliquée par l'unité d'entraînement côté tige ;
(e) positionner un second rivet de test à l'intérieur de l'ensemble ;
(f) contrôler un second signal de sortie de la première cellule de charge et de la seconde cellule de charge tout en refoulant le second rivet de test de façon à déterminer la phase et l'intensité de la force appliquée sur la tête et la tige du second rivet de test respectivement par l'unité d'entraînement côté tête et l'unité d'entraînement côté tige ;
(g) comparer le second signal de sortie de la première cellule de charge et celui de la seconde cellule de charge, qui sont apparus lorsque le second rivet de test a été refoulé ; et
(h) ajuster l'intensité de l'une de la force appliquée par l'unité d'entraînement côté tête et de la force appliquée par l'unité d'entraînement côté tige de telle sorte que l'intensité de la force appliquée par l'unité d'entraînement côté tige soit égale à l'intensité de la force appliquée par l'unité d'entraînement côté tête.

7. Procédé selon la revendication 6, comprenant par ailleurs l'étape consistant à répéter les étapes (a) à (h) jusqu'à ce que les première et seconde unités d'entraînement aient une phase et une intensité dans le temps qui soient sensiblement égales.

8. Procédé selon la revendication 6, comprenant par ailleurs les étapes consistant à répéter les étapes (a) à (h) jusqu'à ce que, au moins dans une zone de maximum de la force dans le temps, les première et seconde unités d'entraînement aient une phase et une intensité qui soient sensiblement égales.

9. Procédé pour commander un rivetage électromagnétique à basse tension d'un rivet à former à l'intérieur de deux pièces de travail, une première des deux pièces de travail comprenant un chanfrein, ledit procédé comprenant les étapes consistant à :

positionner un rivet à former à l'intérieur des deux pièces de travail de telle sorte qu'une tige du rivet dépasse d'une surface d'une seconde pièce de travail sur les deux pièces de travail d'une longueur faisant 0,9 à 1,3 fois un diamètre du rivet ; et la tête du rivet dépasse d'une base du chanfrein d'une longueur qui est de 5 % à 10 % inférieure à la longueur dont la tige du rivet dépasse de la surface de la seconde pièce de travail ;

contrôler la force appliquée dans le temps sur une tête et une tige d'un rivet durant une déformation du rivet sous l'effet du rivetage électromagnétique à basse tension ;

ajuster une phase de la force appliquée sur au moins un d'un emplacement de la tête et de la tige du rivet de sorte que la phase de la force appliquée sur l'emplacement de la tête du rivet soit égale à la phase de la force appliquée sur l'emplacement de la tige du rivet ; et

ajuster une intensité de la force appliquée sur l'emplacement de la tête du rivet et de la tige du rivet de telle sorte que l'intensité de la force appliquée sur la tête du rivet soit égale à l'intensité de la force appliquée sur la tige du rivet.

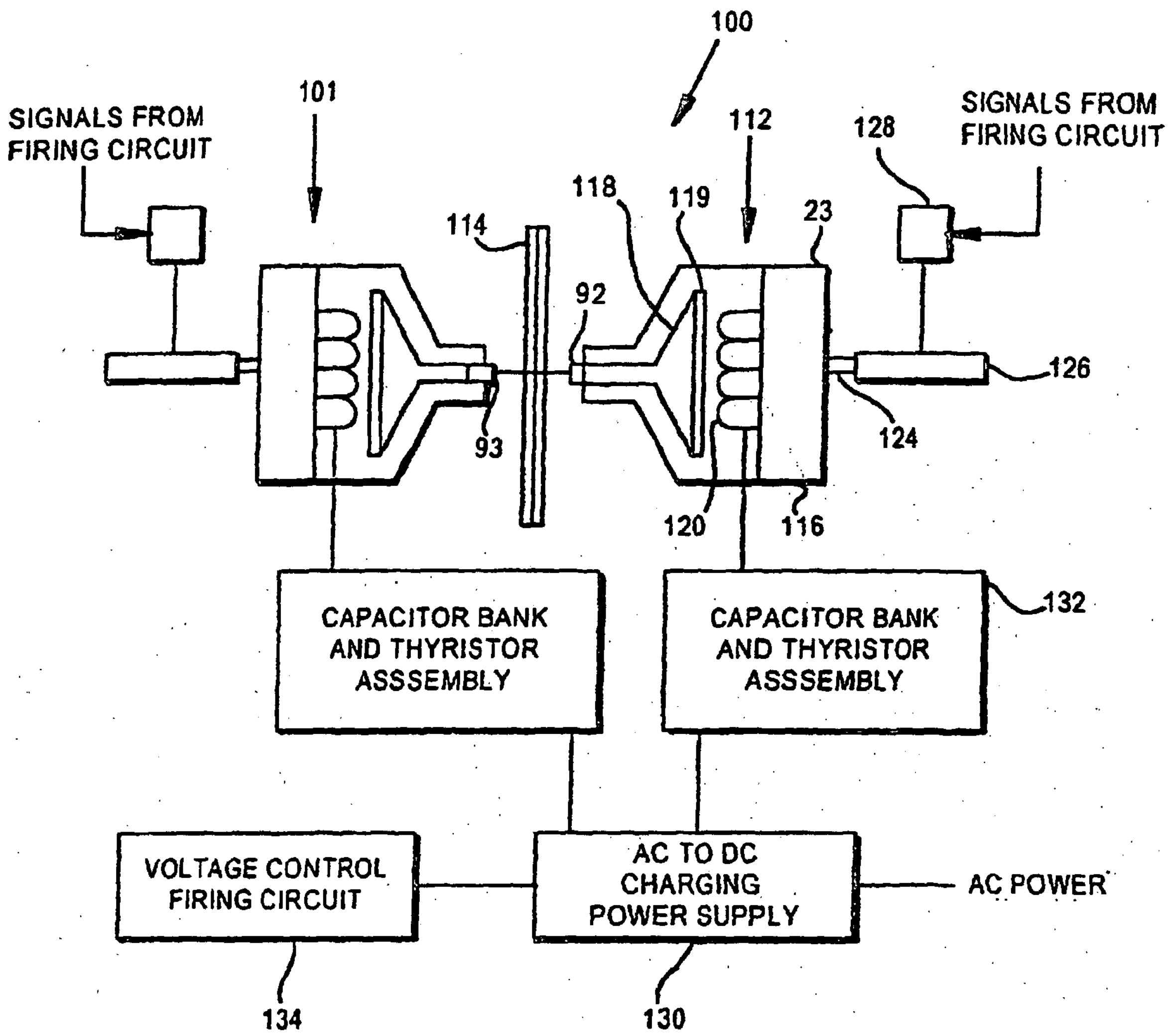


FIG. 1A
PRIOR ART

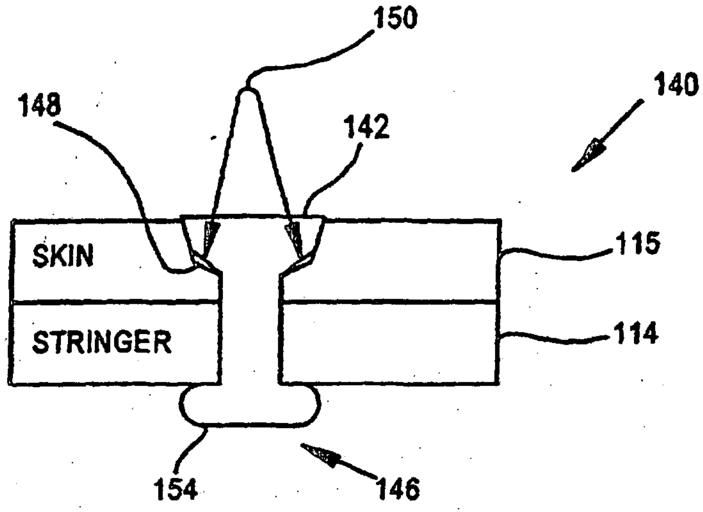


FIG. 1B
PRIOR ART

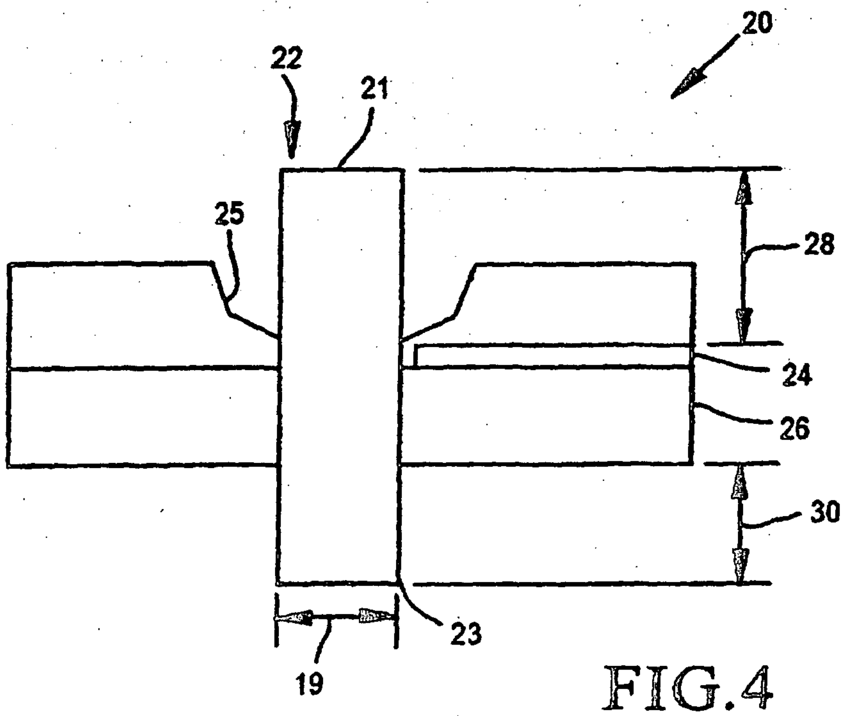


FIG.4

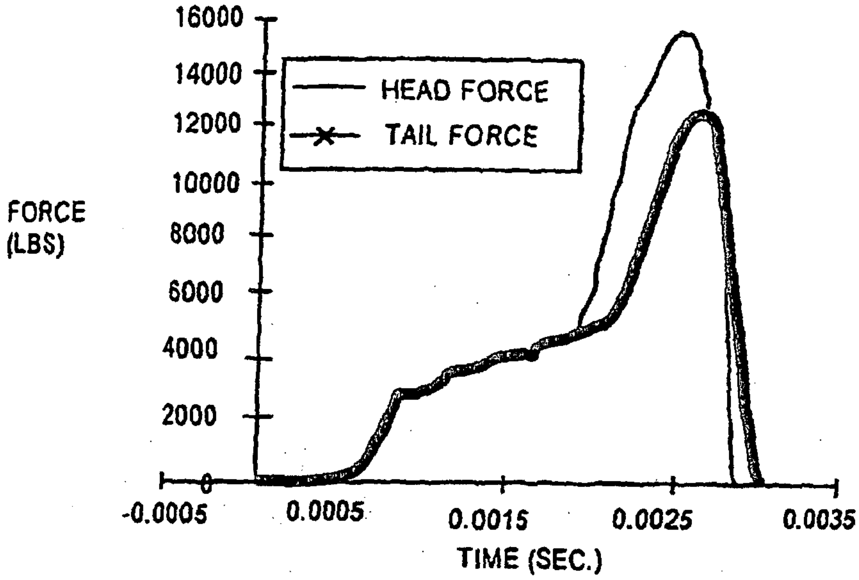


FIG. 2
PRIOR ART

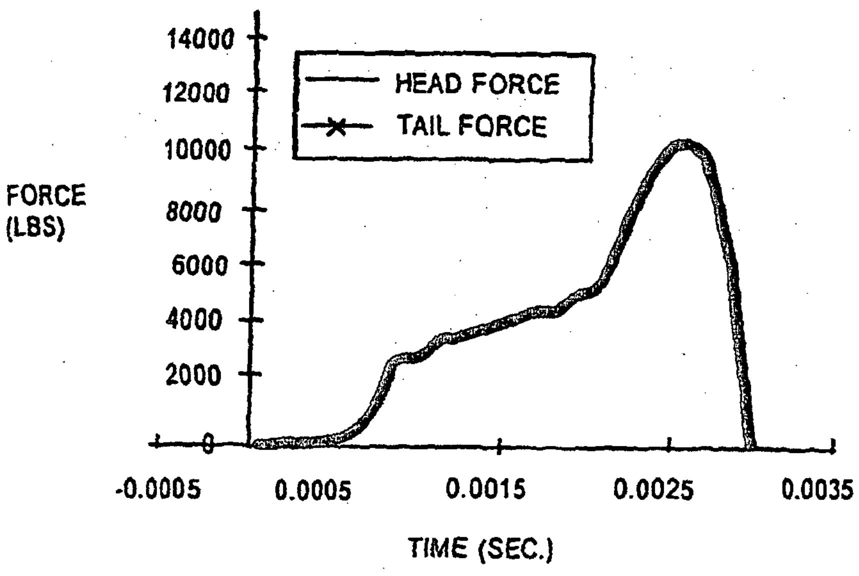


FIG. 3

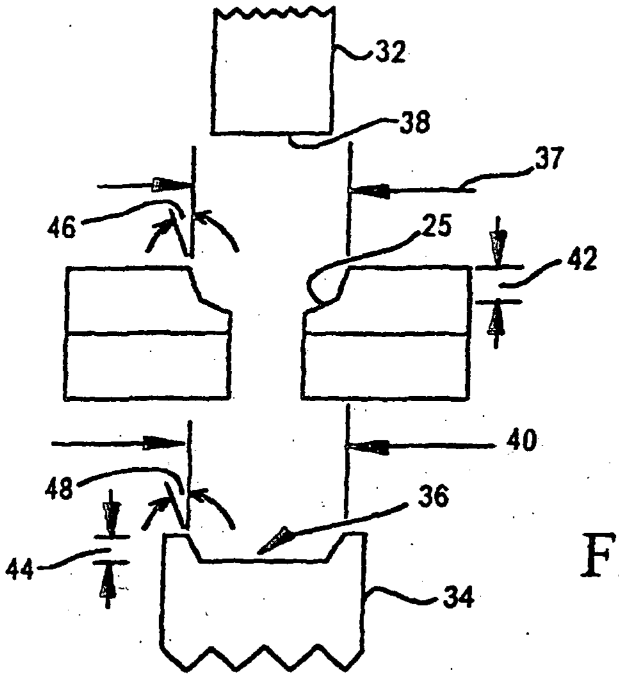


FIG. 5

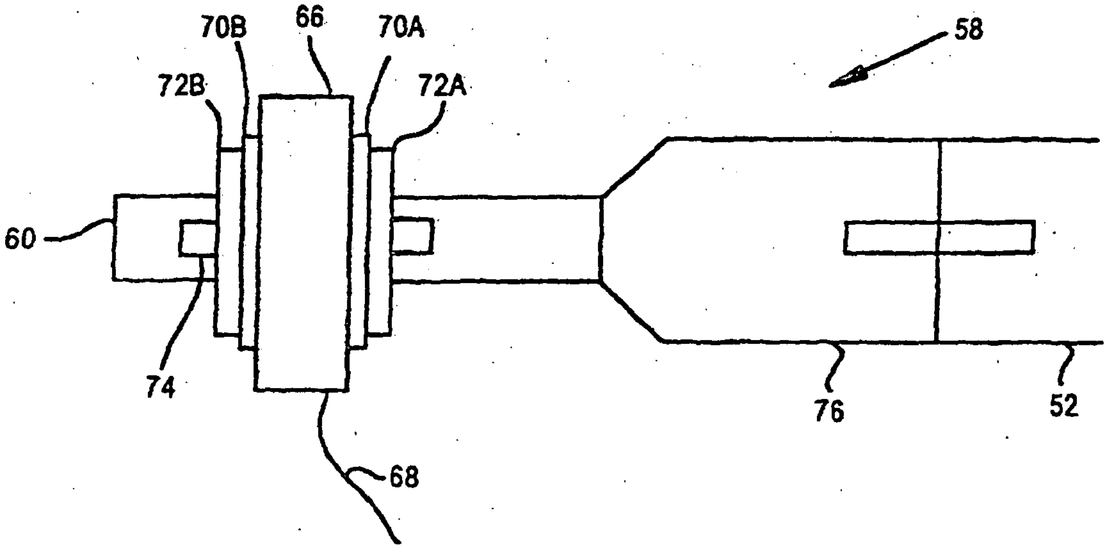
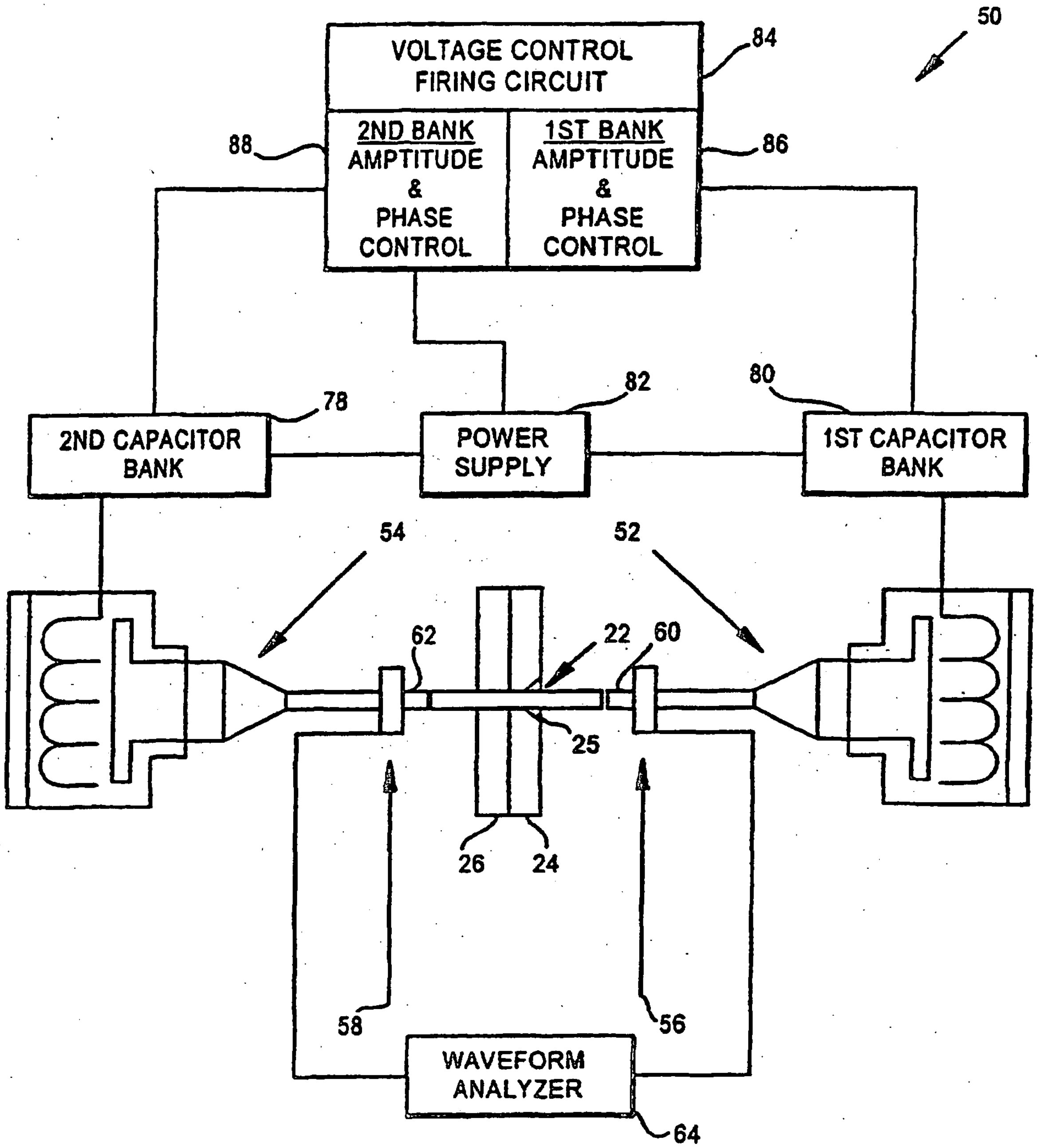


FIG. 6B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AMPTITUDE
&
PHASE
CONTROL
1ST BANK
AMPTITUDE
&
PHASE
CONTROL
2ND CAPACITOR
BANK
POWER
SUPPLY
1ST CAPACITOR
BANK
WAVEFORM
ANALYZER
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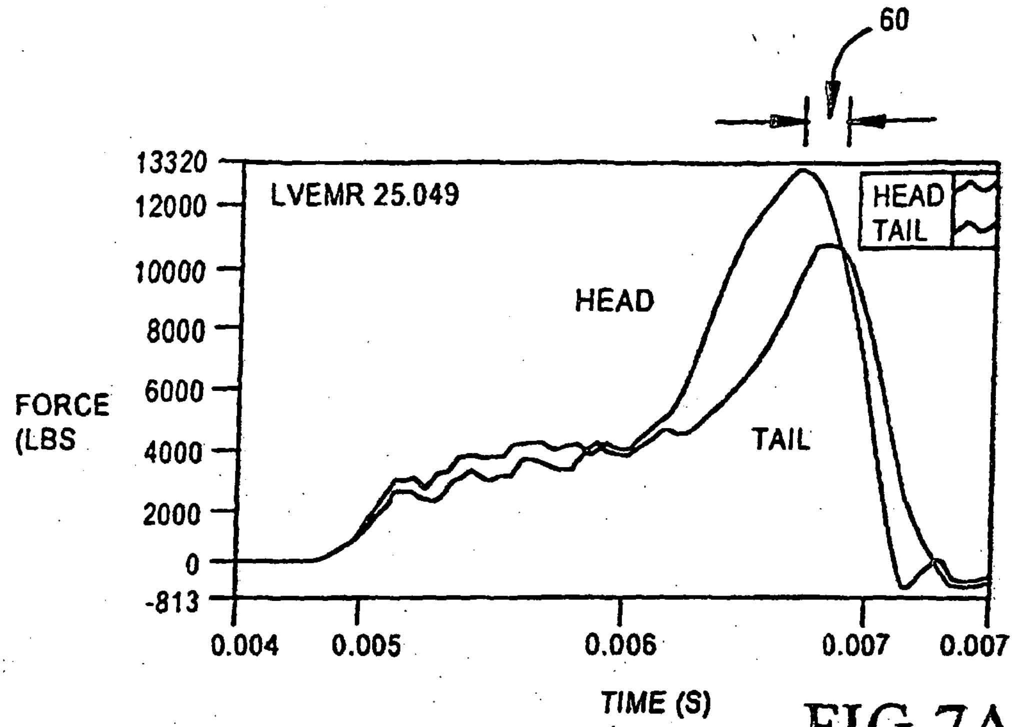
22
60
25
26
24
58
56
64

FIG. 6A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0.006
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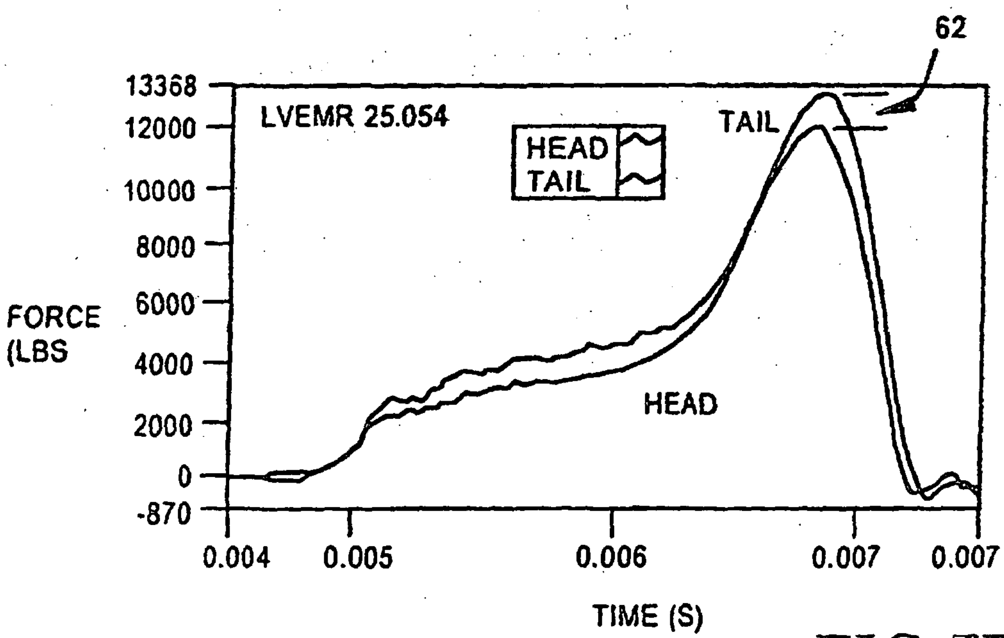
TIME (S)

FIG.7A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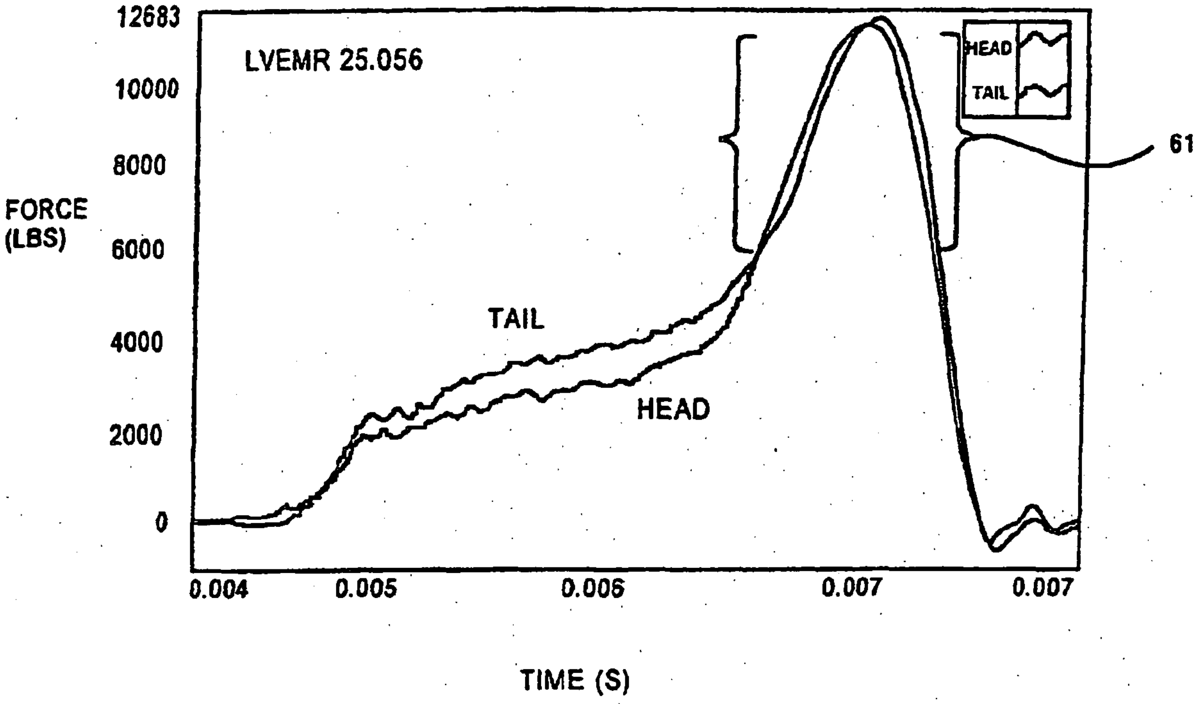
TIME (S)

FIG.7B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TAIL
HEAD
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0.005
0.006
0.007
0.007
TIME (S)

FIG. 7C

REFERENCES CITED IN THE DESCRIPTION

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Patent documents cited in the description

- US 4862043 A **[0005]**
- US 5471865 A **[0008]**